REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	22 July 1999	Final, 1 March 97 - 2 February 98

4. TITLE AND SUBTITLE
Advanced Interface Design Using Force Feedback Hand Controllers, Wearable Computers, and Augmented and Virtual Reality Displays

5. FUNDING NUMBERS
ONR Grant:
N000149710388

6. AUTHOR(S)
Dr. Woodrow Barfield

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Virginia Tech
250 New Engineering Building
Industrial and Systems Engineering Department (0118)
Blacksburg, VA 24061

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Office of Naval Research, Code 1141SB
800 N. Quincy STreet
Arlington, VA 22217

10. SPONSORING / MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION / AVAILABILITY STATEMENT
Distribution Unlimited

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*
The objective of the grant was to establish a research laboratory to design and evaluate augmented and virtual reality environments, wearable computers, and haptic displays. To complete these objectives, SGI workstations, force feedback hand controllers, head-mounted displays, wearable computers, a large-screen projection system, and NT workstations were purchased.

14. SUBJECT TERMS
virtual reality, augmented reality, haptic displays, wearable computers

15. NUMBER OF PAGES
5

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	SAR

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI-Std Z39-18
298-102

FINAL REPORT

GRANT #: N000149710388

PRINCIPAL INVESTIGATOR: Dr. Woodrow Barfield

INSTITUTION: Virginia Tech

GRANT TITLE: Advanced Interface Design Using Force Feedback Hand Controllers, Wearable Computers, and Augmented and Virtual Reality Displays

AWARD PERIOD: 1 March 1997 - 2 February 1998

OBJECTIVE: The objective of the grant was to purchase SGI workstations, force feedback hand controllers, head-mounted displays, wearable computers, a large-screen projection system, and NT workstations to support research in the design and use of augmented and virtual reality environments, wearable computers, and haptic displays.

APPROACH: The approach was twofold: (1) to purchase equipment that would be used to establish a world-class research facility to investigate issues in the design and use of augmented and virtual reality environments, wearable computers, and haptic displays, and (2) to perform empirical studies evaluating the effectiveness of augmented and virtual reality environments, wearable computers, and haptic displays.

ACCOMPLISHMENTS: In addition to purchasing the equipment and establishing the virtual environment laboratory at Virginia Tech, several studies using the equipment have been run. In the area of wearable computers and augmented reality, a study was done to examine how effectively augmented reality (AR) displays, generated with a wearable computer, could be used for aiding an operator performing a manufacturing assembly task. The research concentrated on comparing two technologies for generating augmented reality displays (opaque vs. see-through), with two current types of assembly instructions (a traditional assembly instruction manual vs. computer aided instruction). The study was used to evaluate the effectiveness of the wearable based augmented reality compared to traditional instruction methods, and was also used to compare two types of AR displays in the context of an assembly task.

For the experiment, 15 subjects were asked to assemble a computer motherboard using the four types of instruction: paper manual, computer aided, an opaque AR display, and a see-through AR display. The study was run as a within subjects design, where subjects were randomly assigned the order of instruction media. For the AR conditions, the augmented environments were generated with a wearable computer, and viewed through two types of monocular, head-mounted displays (HMD). The first type of HMD was

a monocular opaque HMD, and the second was a monocular see-though HMD. Prior to the experiment, all subjects performed a brief training session teaching them how to insert the various components of the motherboard in their respective slots. The time of assembly and assembly errors were measured for each type of media, and a questionnaire was administered to each subject at the end of each condition, and at the end of the experiment to determine the usability of the four instructional media.

The results of the experiment indicated that both augmented reality conditions were more effective instructional aids for the assembly task than either the paper instruction manual and the computer aided instruction. The see-through HMD resulted in the fastest assembly times followed by the opaque HMD, the computer aided instruction, and the paper instructions respectively. In addition, subjects made fewer errors using the AR conditions compared to the other two types of instructional media. However, while the two AR conditions were a more effective instructional media when time was the response measure, there were still some important usability issues associated with the AR technology that were not present in the non-AR conditions. Many of the subjects indicated that both types of HMDs were uncomfortable, and over half expressed concerns about poor image contrast with the see-through HMDs.

Augmented reality attempts to aid a user's comprehension of the real world by overlaying meaningful graphics onto corresponding areas of a real scene. In certain applications, particularly medical training and assembly, performance and understanding may be facilitated by an augmented scene perceived as one integrated view and hindered by graphics and the real scene being perceived as separate parts. Medical images designed to be integral with a real body may provide a better training setting than augmented environments that contain graphics clearly not part of the real body under review. In a maintenance or assembly task, more integral images may increase the efficiency and effectiveness of those responsible for maintaining or assembling electronic devices. Three studies were completed to investigate these concepts and assess the impact of integrally designed augmented reality environments. The first study examined various parameters involved with graphic presentation thought to influence integral perception of single graphic augmented scenes. Transparency of graphics, texture, and specific augmented object were factorially investigated. The results showed that a semi-transparent color graphic was perceived as most integral and an opaque outline graphic as the least integral. The second study examined the two extremes of integral graphics from experiment one in augmented environments where multiple graphics were represented in various augmented scenes. As expected, the results for experiment two's high and low integral graphics were perceived as either integral or not. In addition, there was a significant lessening of integral perception as the number of graphics increased from two to eight in the overall scene. The third study was an applied investigation to see if the graphic parameters that indicated high integral perception would yield better performance over low integral graphics for a varied number of graphics in real assembly

tasks. The results showed significantly faster performance for subjects that assembled with the aid of highly integral graphics over those that had poorly integrated graphics.

Another completed study focused on using haptic displays for the visualization of forces for physics, dynamics, and statics problems. The study involved using a force feedback joystick to transmit forces relevant to statics problems to students learning how forces interact upon objects. The results of the study showed that student's understanding of the problem domain was enhanced using the force feedback condition.

A current study in progress examines how wearable computers can be used to aid in performance of a circuit-wiring task using either a wearable computer or paper equivalent instruction. A circuit-wiring task was selected because it is a generic task that is performed across several domains such as airplane assembly, computer assembly, and circuit design. In addition, in contrast to the study highlighted above, this study on wearable computers will focus on the mobile aspects of computing as the task will be performed at several locations.

Prior to the main experimental task, subjects will receive one of three different forms of circuit-wiring training: no prior training, part-task training, or whole-task training. Specifically, subjects receiving whole-task training will be provided all available task instructions while subjects receiving part-task training will be provided only procedural instructions. Following one of the training conditions, subjects will wire a set of temporary circuit configurations from schematics using either a voice-activated text and graphics instructional system run on the wearable computer or a paper-based version as an instructional reference.

The wearable computer used in this study will be a Xybernaut 133P with 32 MB RAM running Windows 95™. The wearable computer will be outfitted with a monochrome monocular VGA head mounted display, noise-canceling microphone and Verbex Listen for Windows 95™ speech synthesis software. Subjects will be University student volunteers with 20/20 or corrected to 20/20 vision who will be unfamiliar with wearable computers and the task.

Performance will be accessed by recording the number of errors committed during circuit wiring and time to task completion. In addition, a usability analysis will be performed evaluating the different instruction technologies. Although it is expected that whole-task training will produce superior performance to part-task and no-task conditions using both forms of instruction, it is anticipated that the no-task and part-task training conditions using the wearable computers will be superior to the no-task and part-task conditions using the paper-based equivalent.

The results will be applicable to computer-based training programs, specifically for part-task training programs seeking to benefit from the use of wearable computers relative to paper instruction. Given the results of the study, we will be able to evaluate the effectiveness of different instructional technologies for on-site training and based on a usability analysis, what features of each technology subjects prefer.

Finally, the first of a series of two studies is currently in progress to investigate the effects of auditory disturbances on presence and performance in virtual environments. Specific factors looked at are the type of noise (speech noise and office noise), the volume of the noise and the effects these have on different types of tasks. As virtual reality systems become more prevalent in the work place, these systems will have to compete for the user's attention with background auditory distractions. The results from this study will provide valuable information into how the auditory distractions affect performance in virtual environments and what can be done to minimize the effects.

CONCLUSIONS: We have shown that force feedback can assist subjects in learning conceptually difficult material. We have also shown that wearable computers are effective instructional technology for maintenance tasks. Future studies will continue to examine when and how advanced virtual reality technology can be used to assist subjects in performance of tasks.

SIGNIFICANCE: Thus far our studies have shown that wearable computers and augmented reality technologies are effective display media for several generic tasks, and specifically are superior to computer-based media and paper instructional media.

PATENT INFORMATION: Not applicable.

AWARD INFORMATION: Dr. Barfield was appointed senior editor for the virtual environments section for the journal "Presence: Teleoperators and Virtual Environments", and was appointed US executive editor for the journal "Virtual Reality: Research, Developments, and Applications".

PUBLICATIONS AND ABSTRACTS:

1. Bystrom, K., and Barfield, W., Collaborative Task Performance for Education Using a Virtual Environment, Presence: Teleoperators and Virtual Environments, 1999.

2. Barfield, W, and Caudell, T., (editors), Fundamentals of Wearable Computers and Augmented Reality, Lawrence Erlbaum Press, scheduled publication 2000.

3. Barfield, W., Baird, K., Shewchuk., J., and Ioannou, G., Applications of Wearable Computers for Manufacturing, in W. Barfield and T. Caudell (Eds) Augmented Reality and Wearable Computers, Lawrence Erlbaum Press, scheduled for publication 2000.

4. Barfield, W., Introduction to Augmented Reality and Wearable Computers, in Barfield and Caudell (Eds) Augmented Reality and Wearable Computers Lawrence Erlbaum Press, scheduled for publication, 2000.

5. Barfield, W., Mann. S., Baird, K., and Cho, G., Computational Clothing and Accessories, in Barfield and Caudell (Eds) Augmented Reality and Wearable Computers, Lawrence Erlbaum Press, scheduled for publication, 2000.

6. Holland. D., and Cho, G., Fundamentals of Computing On and Under the Skin, in Barfield and Caudell (Eds) Augmented Reality and Wearable Computers, Lawrence Erlbaum Press, scheduled for publication, 2000.

7. Mike McGee, Ph.D. student, (Virginia Tech), Integral versus Non Integral Stimuli for Training in Augmented Reality Environments, expected 8-1999.

8. Kevin Baird, Industrial and Systems Engineering (Virginia Tech), The Use of Augmented Reality Environments for Manual Assembly, expected 6-1999.

9. Eric Nash, Industrial and Systems Engineering (Virginia Tech), The Design and Evaluation of Smart Spaces using See-through Displays, expected 9-2000.

10. Greg Edwards Industrial and Systems Engineering (Virginia Tech), Evaluating Ambient Auditory Distracters for Presence and Performance in Virtual Environments, expected 9-2000.